Environmental Science and Policy 101 (2019) 156–165

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Derivation of a climate change adaptation index and assessing determinants and barriers to adaptation among farming households in Nepal

Uttam Khanal*, Clevo Wilson

Queensland University of Technology, Brisbane, Australia

ARTICLE INFO

Keywords:
Adaptation index
Climate change
Determinants of adaptation
Farmers' perception
Multiple linear regression

ABSTRACT

This paper attempts to fulfill the methodological gap in measuring adoption of climate change adaptation practices among smallholder farmers in less developed countries. It explains the derivation of an adaptation index taking into account the importance of adaptation practice and the scale of adoption. Based on information collected through a questionnaire survey of 720 farming households in six districts of Nepal, this study further identifies the factors influencing the farmers adoption of climate change adaptation practices. The multiple regression models revealed 11 variables significantly influencing the adoption of climate change adaptation practices. The variables found significant are age and education of the household head, family size, income sources, access to credit and extension services, number of plots under cultivation, past climate change experience, access to climate information, acceptance of climate change, and belief on adaptation. This indicates that policies aimed at planning and implementation of adaptation programs should emphasize the crucial role of social, economic and attitudinal characteristics of farming households.

1. Introduction

Globally, farmers are needing to make adjustments to their agricultural systems in order to adapt to a changing climatic context. Adaptation of agriculture to climate change is broadly defined as the adjustment of agronomic practices, agricultural processes and capital investments in response to observed or expected climate change threats (Easterling et al., 2007). Although there is a wide range of literature on the impacts of climate change on agriculture (Bandara and Cai, 2014; Dissanayake et al., 2019; Morton, 2007; Wang et al., 2013) and identification of potential agricultural adaptations (Deressa et al., 2009; Gunathilaka et al., 2018; Jawid and Khadjavi, 2019), surprisingly there has been little empirical quantitative analysis on measuring farm level adaptation.

Quantifying the level of adoption of adaptation practices at the household level among smallholder farmers is challenging due to variations in type, intensity, and scale of adaptation. There have been many studies on adoption of adaptation practices (e.g. Deressa et al., 2009; Hassan and Nhemachena, 2008; Piya et al., 2013). Most have employed logit or probit regression model and treat adaptation as a dependent variable in the form of binary or multiple choice (Deressa et al., 2009; Di Falco et al., 2011; Hassan and Nhemachena, 2008). In practice however, there could be variations in the use of adaptation measures. For instance, a single farmer can apply multiple adaptation practices on different scales. A number of other studies have measured adaptation as the total number of adaptation practices employed by the farming households and used them as a dependent variable (Esham and Garforth, 2013; Niles et al., 2016). But in reality, all the adaptation practices are not equally important in adapting to climate change impacts.

A few studies have attempted to quantify vulnerability and adaptive capacity using indices (Below et al., 2012; Hahn et al., 2009). Hahn et al. (2009) developed a livelihood vulnerability index to estimate climate change vulnerability in two districts of Mozambique based on their review of the literature on components of vulnerability. The limitation of their study lies in their use of a balance weighted average approach which assumes each sub-component of the index contributes equally to the overall index. Below et al. (2012) developed an activity-based adaptation index of 33 farm practices and explored the relationship between socioeconomic variables and farmers' adaptation behaviours in Tanzania. Their study addressed the weighting problem by using local expert knowledge for site-specific weighting of indicated variables and sub-components. The weakness of this study is that, in creating an adaptation index, it accounts only for the incidence of various adaptation practices adopted, without considering the scale at which those practices are actually carried out at the farm level.

* Corresponding author. Present address: Department of Jobs, Precincts, and Regions, Agriculture Victoria, Victoria, Australia.
E-mail address: utkhanal@gmail.com (U. Khanal).

https://doi.org/10.1016/j.envsci.2019.08.006
Received 20 January 2019; Received in revised form 16 August 2019; Accepted 16 August 2019

Given the above background, the primary objective of this paper is to address the methodological gap in climate change adaptation studies through deriving an adaptation index by taking into account both the importance of adaptation practices as perceived by the local stakeholders and the actual implementation of particular adaptation practices at the farm level. To this end, the study utilizes farming household level data collected from six districts of Nepal covering all three of the country's ecological regions. The study further assesses the factors that influence farmers' adoption of adaptation practices at the household level. In doing so, we integrate both qualitative and quantitative methods and emphasize differences in farmers' adaptation across major cereal crops grown in Nepal. Given farmers' vulnerability to climate change and its already observed visible impact on Nepal's agricultural sector, it is of utmost importance to investigate what factors persuade farmers to adopt promising farming management practices that can minimize adverse climate change impacts and improve farm production.

Smallholder farmers in less developed countries such as Nepal are some of the most vulnerable to the adverse impacts of climate change (Morton, 2007). There is evidence that Nepal is being significantly affected by increases in extreme temperatures, long periods of drought, unpredictable monsoon rain and reduction in precipitation (Malla, 2009; MoE, 2010). It has been projected that such changes will intensify in the coming decades further exacerbating the vulnerability of poor farmers and negatively affecting agriculture and food security (MoE, 2010).

Agriculture is the economic mainstay of the majority of people in Nepal. It contributes about 35% of the total gross domestic product and employs 70% of the population (MoF, 2014). However, climate change impacts are threatening to undermine farmers' livelihood (MoE, 2010). A typical Nepalese farming household possesses an average landholding of about 0.8 ha and nearly two-thirds of the cultivable land is rainfed (MoAD, 2012). Climate change and the greater climatic variability it brings have substantial effects on the rainfed agricultural system making resource-poor farmers increasingly vulnerable. Several studies have indicated that the adverse impact of climate change on the agricultural sector could be reduced through the implementation of appropriate adaptation strategies (Chhetri et al., 2012; Manandhar et al., 2011). However, in the context of Nepal, little is known about how farmers perceive climate change, how climate interacts with their livelihood strategies, what adaptations have been adopted at farm level and the relative importance of different adaptation practices (Manandhar et al., 2011). Thus, it is essential to explore location-specific impacts of climate change, relevant adaptation practices and the socio-economic factors associated with adaptation. Findings of such research will be helpful for devising appropriate adaptation policies and programs at local and regional levels and more generally be conducive to the promotion of agriculture development. This study is particularly timely given that different adaptation programs have been initiated in Nepal at the national and local levels.[1]

2. Methodology

2.1. Study sites and data collection

Topographically, Nepal is divided into three regions: the Terai in the south, the Hill in the center and the Mountain in the north, and administratively into 77 districts[2] . In this research, two districts from each ecological region were selected: Mustang and Rasuwa from the Mountain region; Kaski and Dhading from the Hill region, and Chitwan and Rupandehi from the Terai region (Fig. 1). The districts were selected purposively to cover a wide geographical area within the central part of Nepal. The field study was conducted by means of randomly selecting two village development committees (VDCs)[3] in each district. The unit of analysis is the farming household, which is the decision-making unit in the agricultural production process.

The selection of farming households from the VDC involved two steps. First, four wards in each VDC were selected randomly. We obtained a list of households in the selected wards from the office of the VDC. Then, we identified households involved in farming in each randomly selected ward. In the next step, we selected farming households from each ward through simple random sampling. We selected 15 households from each ward, producing a total sample size of 720.

A combination of different methods was used for the data collection. These methods include focus group discussions (FGD), stakeholder workshops and household surveys. The data collection for this study was carried out from October 2015 to January 2016. The goal of FGDs was to gather insights on aspects of research themes that cannot be addressed by household surveys alone. One FGD was conducted in each VDC. The participants consisted of 8–10 farmers who were long-time residents of their respective VDCs and included both men and women. This followed an informal, semi-structured interview format lasting about 2 h. Through the FGDs we collected information regarding general characteristics of villages under study, farmers' perceptions of climate change, impacts on agriculture, adaptation strategies and crop specific adaptation practices. To ensure that the adaptation practices that farmers adopt were a consequence of climate change and not due to other pressures, we asked three contingent questions[4] ; 1) do you perceive any changes in the local climatic condition in the last 15–20 years? If yes, what are they? 2) What have been the impacts of these changes in agriculture production? 3) What have you done to deal with these changes? The identified adaptation practices were then included in the household survey questionnaire used to examine the actual adaptations by the sampled households.

One stakeholder workshop was conducted in each ecological region. Perception of farmers about climate change and adaptation practices that were identified through FDGs were shared among the participants in the workshop. The participants consisted of local agricultural and extension experts from governmental and non-governmental organizations, leading farmers and key informants in the area. The main objective of the workshops was to assign the weights for identified adaptation practices based on feasibility, effectiveness and sustainability.

The household survey was commenced after the FGDs and stakeholder workshops were completed. Prior to administering the questionnaire to the sampled households, a pre-testing with the non-sampled households was carried out in order to examine the applicability of the questionnaire. The survey questionnaire was finalized incorporating the inputs from pre-testing, focus group discussions and stakeholder workshops. The household level data on perceptions of climate change, impacts on agriculture, adaptation practices and socio-economic characteristics, were drawn from the household survey. The household survey was carried out through a face-to-face interview with the

[1] The government of Nepal prepared the National Adaptation Program of Action (NAPA) in 2010 which identified well-defined priorities for climate change action. Climate Change Policy was proclaimed by the Nepalese government in 2011 to promote climate adaptation and mitigation in response to the international climate regime. A Local Adaptation Plan of Action (LAPA) framework was also developed in 2011 which provides opportunities to assess site-specific climate vulnerabilities and identify and implement adaptation actions.

[2] Before the administrative reform of 2017, there were 75 districts in Nepal.

[3] A VDC is an administrative unit in Nepal similar to a municipality which is further divided into nine wards. Each ward constitutes one to several villages. But, the administrative divisions in Nepal underwent changes after the administrative reform in 2017, when the VDCs were replaced by rural municipalities.

[4] These questions were also included in the household survey questionnaire.

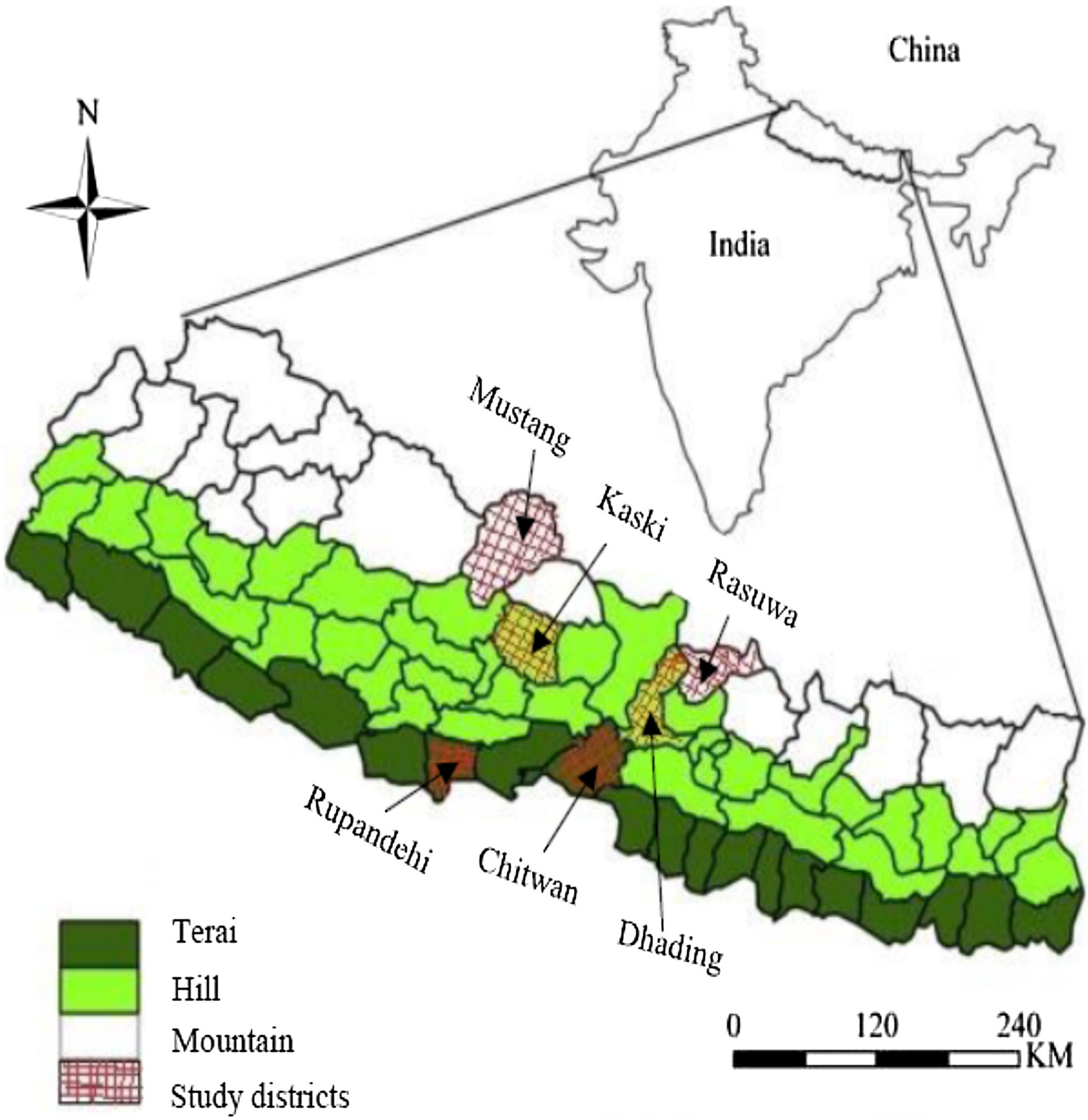

Fig. 1. Map of Nepal showing the ecological regions and the study districts.

decision maker of the sampled farming households, who could be an adult of any gender. The interview was conducted in Nepali language and took approximately one hour to complete. We recruited four enumerators[5] from the Agriculture and Forestry University in Nepal for the household survey. Prior to conducting the household survey, the enumerators were given training on how to collect data appropriately. They were briefed on the context, purpose and expected outcome of the study. Each question in the questionnaire was discussed in the training and it was confirmed that enumerators understand all the questions. Furthermore, they were made aware of the confidentiality of the collected data.

2.2. Farmers' perception of climate change and associated impacts

We collected responses from 720 individuals on six indicators of changes in weather parameters and seven indicators of climate change impacts on agriculture using semi-structured questionnaires. As mentioned above, these indicators were identified from FGDs with farmers in the study area held before the household survey. The respondents were asked whether they have experienced or noticed the changes in given indicators. Three options were provided for the weather parameters indicators: 'increase,' 'stable' and 'decrease.' Similarly, three options were provided for impacts on agriculture: 'Yes,' 'No' and 'Don't know.' For each indicator included in the survey, we calculated frequencies and percentages of responses.

[5] All the recruited enumerators had completed their bachelor degree in agricultural science. We selected agriculture graduates as the major portion of the questionnaire included questions related to agriculture.

2.3. Adaptation index

To investigate farmer adaptation practices, we first identified those that are currently used by farmers in the study area through a review of the literature and the FGDs with farmers in respective villages. While farmers have implemented various adaptation practices in dealing with climate change, they have not been equally important in minimizing its adverse impacts. Some practices are more effective, feasible and sustainable than others. Therefore, we conducted stakeholders' workshops[6] in each agro-ecological region to assign weights to adaptation practices. Through thorough interaction with stakeholder participants, scores were assigned for each adaptation based on effectiveness, feasibility, and sustainability[7] . A 10-point Likert scale was used for rating the practices based on all three criteria: 10 representing very effective and 0 being not effective at all. Similarly, scores for feasibility and sustainability were given based on a 10 points scale. These three scores were then added to obtain the total weight of an adaptation practice. Through the household survey, we assess the actual adaptation practices used by farmers in their farmlands.

Following Below et al. (2012) we calculated adaptation as the sum of the weighted adaptation practices of the farmer:

$$AIj = w_1 v_{1j} + \dots\dots\dots w_n v_{nj} \quad (1)$$

where,

AIj = adaptation index of household j;

W_1 = weighting factor of adaptation practice 1;

V_{1j} = jth household value for practice 1 (this takes the value 1 if the jth household adopted practice 1 and 0 if not adopted).

For specific crops, we calculated the adaptation index based on the number of years and the percentage of the area in which the particular adaptation practice is exercised by an individual farmer. In the above formula, the crop specific adaptation index of an individual farmer V_{1j} is given by:

V_{1j} = jth household's value for practice 1 with respect to the numbers of years and area of practice implementation. Thus:

$$V_{1j} = y_{1j} * a_{1j} \quad (2)$$

where,

y_{1j} = 1 if the household j is implementing practice 1 for less than 2 years.

2 if the household j is implementing practice 1 for 2–5 years.

3 if the household j is implementing practice 1 for more than 5 years.

and a_{1j} = proportion of total area under practice 1 of the Jth household.

2.4. Determinants of adaptation

To investigate the determinants of climate change adaptation, either a simple linear regression model or a complex analytical model comprising several dependent variables can be employed. In this study, our objective is to analyze in a simple way the factors influencing the adoption of climate change adaptation practices. As we have a single dependent variable – the adaptation index - that takes into account all the adaptation practices adopted by farming households, a simple multiple linear regression model is appropriate. To utilize the multiple regression analysis, the dependent variable - the adaptation index - is hypothesized as being influenced by a set of independent variables (Table 1). We included a number of explanatory variables[8] based on the review of the literature. Farmers' level of education, availability of credit and access to extension services are factors that are found to support farmers' adaptation (Hassan and Nhemachena, 2008). Other factors include farmers' perceptions of climate change and the social capital effect of farmers' decisions to employ adaptation to climate change (Nielsen and Reenberg, 2010; Piya et al., 2013). Lack of information about climate change and adaptations, financial constraints, and shortage of land are identified as the major barriers to the successful adaptation to climate change in agriculture (Deressa et al., 2009; Grothmann and Patt, 2005; Measham et al., 2011).

Frequently discussed in the literature is that the number of years of experience in agriculture is positively associated with the adoption of improved agricultural practice. A Study by Deressa et al. (2009) indicates that age of the household head increases the probability of climate change adaptation through planting trees and increasing irrigation. Hassan and Nhemachena (2008) show that the more experienced farmers are more likely to adapt than the less experienced. The age of the household head is found to affect farmers' decision to adapt to climate change. Several studies found a positive relationship between the age of the household head and farming households' decision to adapt (Deressa et al., 2009; Hassan and Nhemachena, 2008). However, other studies have reported a negative connection between the age of the household head and the adoption of improved agricultural practices (Anley et al., 2007; Nyangena, 2008).

It is generally believed that a higher level of farmers' education is associated with better access to information on improved technologies. Thus, farming households with a higher level of education of the household head are more likely to adopt climate change adaptation strategies (Deressa et al., 2009). Studies on the adoption of improved agricultural technologies also indicate that household size has positive effects on adoption. A large family means a greater labour force which would support a household to adopt labour intensive agricultural technology (Croppenstedt et al., 2003; Deressa et al., 2009). Furthermore, it is argued that as the opportunity cost of labour might be low in rural areas of most developing countries, farm households with more labour are more likely to take up adaptations (Hassan and Nhemachena, 2008).

Information provided by extension agents facilitates farmers in their decisions on how and when to use innovations including climate change adaptation strategies. Deressa et al. (2009) and Hassan and Nhemachena (2008) show a positive association between farmers access to extension services and adaptation to climate change. Furthermore, farmers can obtain information on improved farm management practices and innovations from farmers' organizations and social networks thereby increasing the likelihood of adoption (Abdulai and Huffman, 2014). Similarly, information on climate change increases the probability of using different crop varieties as an adaptation strategy to combat climate change impacts (Deressa et al., 2009).

For resource-poor farmers, the involvement of family members in non-farm activities may reduce financial constraints, allowing them to use such income on productivity increasing inputs. Deressa et al. (2009) indicate that non-farm income increases the likelihood of planting trees, changing planting dates and using irrigation as adaptation options. However, it is also argued that participation in non-farm activities may impede the involvement in farm production activities (Abdulai and Huffman, 2014). Deressa et al. (2009) found that access to credit has a

[6] One stakeholder workshop was organized in each ecological region to assess the importance of different adaptation practices identified through the FGD.

[7] To ensure that all the participants in the workshop attained the same understanding, the operational definition of these criteria as used in this research were explained in the workshop. Feasibility was defined as 'how easily can the given adaptation practice be adopted?' Effectiveness was defined as 'to what extent does the given adaptation practice have the potential to minimize negative impacts imposed by changes in local climatic conditions?' Sustainability was defined as 'for how long (how many years) does the given adaptation practice work once adopted?

[8] A multivariate correlation analysis was carried out to find out the extent of collinearity between the explanatory variables. The variables included in the model exhibit a low degree of correlation ($r < 0.5$) with each other.

Table 1
Variable names, definitions and descriptive statistics for the sample.

Variable	Description	Sample mean	Std. Dev.
Age	Age of the household head	45.79	13.70
Education	Education of the household head in number of years	7.65	3.41
Family size	Family size	6.06	2.49
Land[a]	Land holdings in hectares	0.55	0.21
Non-farm	Dummy = 1 if any member of the family involved in non-farm job, 0 otherwise	0.68	
Credit	Dummy = 1 if the household has access to credit, 0 otherwise	0.57	
Extension	Dummy = 1 if household has received information from extension agent, 0 otherwise	0.49	
Market	Distance from house to market (km)	8.45	10.25
Institution	Dummy = 1 if any member of the household was member of agricultural related groups and organizations, 0 otherwise	0.69	
Drought/Flood	Dummy = 1 if the household was affected by drought or flood during the last five years, 0 otherwise	0.35	
Plots[b]	Number of farm plots under cultivation	2.91	1.20
Climate information	Dummy = 1 if the household received information on climate change, 0 otherwise	0.38	
Climate belief	Dummy = 1 if the respondent believes climate has changed in the local area, 0 otherwise	0.83	
Adaptation belief	Dummy = 1 if the respondent believes adaptation minimizes negative climate change impacts on agriculture production, 0 otherwise	0.52	

[a] Land is measured as the area under a particular crop for crop specific analysis.
[b] Plots are measured as the number of farm plots under a particular crop cultivation for crop specific analysis.

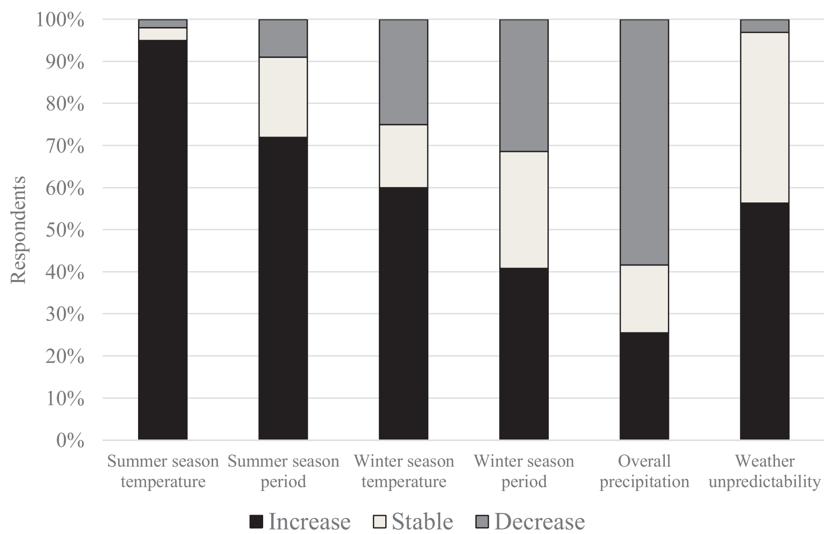

Fig. 2. Farmers' perception of trends in weather parameters.

positive and significant impact on the likelihood of using soil conservation, changing plating dates and using irrigation as adaptation strategies to combat climate change impacts in the Nile basin of Ethiopia. Moreover, Hassan and Nhemachena (2008) reveal a strong positive influence of access to credit services on the probability of adopting adaptation measures. Their study further shows that better access to a market is critical for helping African farmers adapt to climate change.

Specifically, we included household characteristics such as age, education, family size, involvement in non-farm activities and farm characteristics such as land holding size, number of cultivated farm plots and whether the household is affected by droughts and floods. As is typical in least developed countries, many farmers in Nepal suffer from information, market and credit constraints which are important factors in determining the adoption of adaptation strategies. Thus, before they can consider applying climate change adaptation strategies to their farmlands, farmers must have information on climate change, an understanding of the changes in local climatic condition and equally an understanding of how adaptation minimizes negative climate change impacts. Therefore, we included access to climate information, farmers' belief on changes in local climatic conditions and belief that adaptation minimizes the adverse impact of climate change, as the factors believed to influence farmers' decision to adopt adaptation practices.

3. Results

3.1. Sample characteristics

Table 1 presents the descriptive statistics of the sampled households. The average age of the household head was 46 and who attained, on average, eight years of schooling. On average there were six members in a family which owned an average of 0.55 ha of land. The average distance from the house to market was 8 km. On average, the sampled household cultivated about three plots of farmland. The survey results show that about 68% of farming households had at least one member involved in a non-farm job, 57% had access to credit, 49% had received information from extension agents, and 69% had at least one member associated with agricultural related organizations. About 35% of the respondents reported that their household was affected by drought or flood in the last five years; 38% received information on climate change; 83% believed that climate has changed in their area and 52% believed that adaptation minimizes the negative impacts of climate change on agriculture production.

3.2. Farmers' perception of changes in weather parameters

Fig. 2 presents the respondents' perception of the trends of weather parameters in the study area compared to the previous 15–20 years.

Most of the respondents (95%) perceive the summer season temperature has increased whereas 60% reported that they experienced an increase in winter season temperatures in recent years. These results are similar to those reported by other studies carried out in Nepal where the majority of the respondents experienced increasing temperatures (Khanal, 2014; Manandhar et al., 2011; Piya et al., 2012). Respondents' perception of precipitation was provided in terms of rainfall and snowfall quantity. 58% perceived that overall precipitation has decreased in recent years; 56% observed unpredictable weather patterns over the past 20 years and 41% noticed no change in predictability.

3.3. Farmers' perception of climate change impacts on agriculture

Nearly 95% responded that changing climate had negatively impacted their agricultural production and productivity. About 5% reported no impact. Some farmers in the Mountain region reported that changing climate had a positive impact on their agriculture system. They noted that they were able to grow new vegetables such as cauliflower, cabbage, tomato and cucumber over the past few years, an achievement due to the warmer temperature in recent years. Nearly 85% and 80% of respondents experienced more droughts and a reduction in irrigation water availability respectively (Table 2). Almost 78% noted an increase in flooding and landslides. A substantial majority of respondents experienced an increased in infestation of insects in crops, an increase in crop diseases (83.1%) as well as the introduction of invasive species in farms (75.3%). A total of 81.6% of respondents perceived there had been a degradation of soil in their farmlands and 73.6% experienced a decline crop yields in recent years due to the impact of climate related changes.

3.4. Climate change adaptation in the study sites

In response to long-term perceived changes in climatic parameters, Nepalese farm households have undertaken a number of adaptation measures. A total of 24 practices were identified through a literature review and FGDs with farmers in the study sites. The identified practices are categorized into five groups: crop and varietal adjustment, adjustment in the timing of farm operations, soil and water management, fertilizer management and off-farm adjustment.

The household survey results showed that 91% of the farming households had undertaken at least one adaptation measures in response to the changing climate (Table 3). The most commonly employed adaptation measure is the change in planting and harvesting date (42.5%) followed by growing diverse crops and varieties (39.4%), farm yard manure management (36.9%) and improving or increasing irrigation (33.2%). However, a smaller percentage of farmers have adopted adaptation measures such as livelihood diversification, rainwater harvesting and growing drought tolerant crops/varieties. Farmers explained that low adoption of these practices is due to the lack of information and technical know-how about such crops and varieties (Table 3).

The importance of the adaptation practices based on their effectiveness, feasibility and sustainability are shown in Table 4. The weight ranges between 4 and 26. As ranked by the local stakeholders, the relatively important practices are improving and increasing irrigation, agroforestry, farm yard manure management and growing diverse crops and varieties with the average score of 23.7, 22.3, 22.0 and 21.7 respectively. The frequencies of adaptation practices and their respective weights generated from the stakeholder workshops were used to calculate the adaptation index for the individual farming household. The average adaptation index is 90.1 ranging from 0 to 296.7.

Table 2
Farmers' perception of climate change impacts on agriculture.

Impacts	Percent of respondents		
	Yes	No	Don't Know
Increase in intensity and duration of drought	84.7	3.1	12.2
Reduction in irrigation water availability	79.7	9.6	10.6
Increase in flooding and landslides	78.2	8.6	13.2
Increase in crop diseases and insect infestation	83.1	7.6	9.3
Introduction of invasive species/more weeds	75.3	9.3	15.3
Soil degradation	81.6	6.9	11.5
Decline in crop yields	73.6	7.6	18.9

Table 5 presents the details of adaptation practices adopted by farmers for rice, maize and wheat fields. In rice fields, improved and increased use of farm yard manure and growing drought-tolerant varieties are the most commonly adopted adaptation practices, while improved and increased use of farm yard manure and chemical fertilizers are the most frequently exercised practices for maize cultivation. Moreover, increasing seeding rates and growing disease and pest resistant varieties are often used as adaptation methods for wheat cultivation (Table 5). Using Eqs. 1 and 2, we calculated farming households' adaptation indexes for each crop. The results show the average adaptation indices per farming household for rice, maize, and wheat are 76.8, 67.1 and 53.5 respectively.

Although only about 9% of farming households did not adopt any adaptation practices, a large percentage of farmers adopted very few practices. The findings show that for most farmers, lack of awareness about adaptation practices and the extra burden of on-farm work were the most important barriers to adaptation (Table 3). For adaptation measures such as improved use of chemical fertilizer and keeping more livestock, farmers reported weak financial capacity as the major barrier. Some of the adaptation practices such as terrace construction are not applicable to most farms. A number of studies find a significant positive impact of adaptation practices on crop productivity (Di Falco et al., 2011; Huang et al., 2015; Khanal et al., 2018). Thus a large percentage of farmers could improve their agricultural production by adopting appropriate adaptation practices against climate change impacts.

3.5. Determinants of adaptation

Table 6 presents results of a multiple regression analyses representing the determinants of adaptation. The coefficient of age is negative and significant in terms of their effect on climate change adaptation by farming households indicating that relatively younger farmers are more likely to adopt adaptation practices than the older ones. The coefficient of education is positive and significant in all the models suggesting that better-educated farmers are more likely to employ adaptation practices. This result is consistent with the findings of Deressa et al. (2009) in their study of Ethiopian agriculture and Alauddin and Sarker's (2014) study of Bangladesh agriculture. However, in the case of Nepal, the educational level of farmers in the study area is poor (Table 1). Thus there is the need for easier access to education among farmers in order to enhance the adoption of adaptation measures.

Results indicate that the smaller the household size, the higher is the likelihood of adoption. However, this is not statistically significant in maize and wheat farming. Moreover, households with non-farm income are more likely to adopt adaptation practices. The credit variable is positive in all the models and significant in all models except for maize farming. This indicates that farming households with access to credit are more likely to adopt adaptation practices - a finding which supports Di Falco et al.'s (2011) study of Ethiopian agriculture. Similarly, farmers who received information from extension agents are shown to be more likely to adopt adaptation practices indicating the positive effects of extension services on adaptation (Deressa et al., 2009; Hassan and Nhemachena, 2008). In our study area, only 57% and 49% of farmers had access to credit and extension services respectively. This suggests the need for improvement of such services in order to increase the uptake of adaptation practices.

Table 3
Adoption of adaptation practices.

Adaptation practices	Adoption rate (%)	Barriers for adaptation (%)
No adaptation	8.89	Lack of awareness of adaptation (73), extra burden on on-farm work (19), Lack of money (26), lack of labour (22)
Crop/varietal adjustment		
Grow diverse crops/varieties	39.44	LIP (73), OFC (5), LTK (14), NUF (5), RME (3)
Grow drought-tolerant crops/varieties	9.72	LIP (66), OFC (7), LTK (23), NUF (3), RME (1)
Grow short duration crops/varieties	18.06	LIP (65), OFC (4), LTK (29), NUF (2), RME (0)
Grow insects/diseases resistant crops/varieties	12.50	LIP (63), OFC (9), LTK (28), NUF (0), RME (0)
Grow less water intensive crop/varieties	27.64	LIP (55), OFC (7), LTK (30), NUF (4), RME (4)
Crop rotation	25.83	LIP (35), OFC (1), LTK (52), NUF (5), RME (7)
Intercropping/mixed cropping	21.11	LIP (49), OFC (2), LTK (32), NUF (4), RME (13)
Change planting locations of crops	18.06	LIP (59), OFC (6), LTK (19), NUF (13), RME (3)
Farm operations time adjustment		
Change planting date/ harvesting date	42.50	LIP (58), OFC (7), LTK (16), NUF (11), RME (8)
Adjustment in time of weeding, pesticide application	9.31	LIP (29), OFC (3), LTK (51), NUF (8), RME (9)
Soil and water management		
Mulching	10.14	LIP (54), OFC (0), LTK (32), NUF (0), RME (14)
Cover crops	13.33	LIP (43), OFC (8), LTK (38), NUF (5), RME (6)
Reduce tillage	9.03	LIP (58), OFC (4), LTK (35), NUF (3), RME (0)
Fallowing	6.81	LIP (33), OFC (1), LTK (7), NUF (59), RME (0)
Terrace construction	10.56	LIP (38), OFC (14), LTK (11), NUF (2), RME (35)
Agroforestry	25.83	LIP (26), OFC (6), LTK (43), NUF (3), RME (22)
Rain water harvesting	8.19	LIP (32), OFC (20), LTK (13), NUF (13), RME (22)
Flood control	19.58	LIP (41), OFC (3), LTK (7), NUF (39), RME (10)
Improve/increase irrigation	33.19	LIP (44), OFC (18), LTK (28), NUF (4), RME (6)
Fertilizer management		
Improve/increase chemical fertilizer use	28.19	LIP (49), OFC (31), LTK (13), NUF (3), RME (4)
Improve/increase farm yard manure use	36.94	LIP (69), OFC (6), LTK (15), NUF (0), RME (10)
Off-farm adjustment		
Keep more livestock	8.75	LIP (11), OFC (35), LTK (7), NUF (28), RME (19)
Weather forecasts	8.89	LIP (48), OFC (0), LTK (41), NUF (0), RME (11)
Livelihood diversification	6.94	LIP (56), OFC (9), LTK (30), NUF (0), RME (5)

LIP = Lack of information about the practice, OFC = over my financial capacity, LTK = Lack of technical knowhow, NUF = Not useful to my farm, RME = requires too much effort.

The coefficient of drought/flood is positive and significant in all the models, suggesting that farming households affected by drought and flood in the last five years are more likely to employ climate change adaptation practices in their farming than those that are not affected. Alauddin and Sarker (2014) found similar results in a study of Bangladeshi farmers. The signs for variable plots are also positive and the coefficients are significant except for wheat farming. This, indicates that households cultivating crops in a greater number of plots are more likely to adopt adaptation strategies. Interestingly, the effects of climate information, climate belief, and adaptation belief are all statistically significant in all the models. Specifically, the positive and significant coefficient of climate information indicates that farmers who receive information on climate change are more likely to adapt to climate change. This is in line with the findings of Deressa et al. (2009). Furthermore, those farmers who believe that local climatic conditions have changed are more likely to adapt. Also, farmers who believe that adaptation minimizes the negative impact of climate change on agriculture are more likely to employ adaptation strategies. These results suggest the need for awareness raising and capacity building activities among farmers that enhance their understanding of climate change issues.

4. Discussion and conclusion

This study contributes to the growing body of literature on documenting and measuring response strategies against climate change impacts adopted by smallholder farmers. By creating an adaptation index which incorporates the actual level of adoption, this study provides a novel approach to measuring farm level adaptations. In response to the adverse impacts of climate change, farmers have adopted several adaptation practices. A number of studies have attempted to create an adaptation index in order to measure the level of adaptation (Below et al., 2012; Esham and Garforth, 2013; Niles et al., 2016). However, in creating such an index, previous studies did not take into account the scale at which the adaptation practices are utilized by farmers. In our study, 24 different practices were identified with 91% of the farming households employing at least one practices. A large percentage of farmers had adopted diverse practices. In such cases, one way of measuring household level adaptation is to count the total number of practices adopted by farming households. However, our study reveals that different adaptation practices employed by farmers are not of equal importance in minimizing climate change impacts. In addition, results show that farmers have adopted different practices on different scales. Therefore, there is a need to develop an integrated index that can capture both the importance of adaptation practices and the actual scale of adoption at the farm level. In this context, our adaptation index has the capacity to provide policymakers with a clear and comprehensive picture of farmers' actual adaptation which in turn can support them in making better-informed decisions regarding farming practices. A comparison of adaptation indexes among farmers or between groups provides information on the differences in the actual level of adaptation between them. It can be an effective way of examining the adaptation gap among farming households or communities and can be of support in adaptation planning at the local level.

Understanding how farmers perceive the impact of changes in local climatic conditions on their agricultural production, and how socioeconomic factors affect their likelihood to adopt adaptation practices, is critical for developing effective response strategies against climate change impacts (Li et al., 2017). From this study, it is evident that a large percentage of farmers in Nepal are perceiving gradual changes in local climatic conditions. Additionally, farmers are perceiving that these changes are affecting their agricultural production. This perception is quite similar to other studies conducted in Nepal (Chaudhary and Bawa, 2011; Piya et al., 2012). Moreover, our findings on farmers'

Table 4
Weighting of adaptation practices by ecological regions based on effectiveness, feasibility, and sustainability.

Adaptation practices	Adaptation weights			
	Terai	Hill	Mountain	Total average
Crop/varietal adjustment				
Grow diverse crops/varieties	21	22	22	21.7
Grow drought tolerant crops/varieties	18	23	20	20.3
Grow short duration crops/varieties	15	16	18	16.3
Grow insects/diseases resistant crops/varieties	19	18	17	18.0
Grow less water intensive crop/varieties	18	20	19	19.0
Crop rotation	19	18	17	18.0
Intercropping/mixed cropping	16	19	16	17.0
Change planting locations of crops	12	18	13	14.3
Farm operations time adjustment				
Change planting date/ harvesting date	20	19	16	18.3
Adjustment in time of weeding, pesticide application	13	7	10	10.0
Soil and water management				
Mulching	15	15	9	13.0
Cover crops	14	14	10	12.7
Reduce tillage	10	19	17	15.3
Fallowing	6	4	6	5.3
Terrace construction	10	19	17	15.3
Agroforestry	18	26	23	22.3
Rain water harvesting	18	17	16	17.0
Flood control	20	19	9	16.0
Improve/increase irrigation	22	25	24	23.7
Fertilizer management				
Improve/increase chemical fertilizer use	19	15	15	16.3
Improve/increase farm yard manure use	23	21	22	22.0
Off-farm adjustment				
Keep more livestock	10	19	15	14.7
Weather forecasts	14	17	16	15.7
Livelihood diversification	17	20	18	18.3

perceptions of changes in weather parameters are comparable to other studies. Farmers' observations on climatic variability differ considerably across geographical regions (Below et al., 2012). These perceptions include increasing temperature and decreasing precipitation in the Nile basin of Ethiopia (Deressa et al., 2009), in the Sekyedumase district of Ghana (Fosu-Mensah et al., 2012), in the Osun state of Nigeria (Sofoluwe et al., 2011), in the southwest region of Uganda (Osbahr et al., 2011), in the Madhya Pradesh of India (Halder et al., 2012) and in the Rewa Delta region of Fiji (Lata and Nunn, 2012). Perceptions of an increased frequency and intensity of drought is recorded in Bangladesh (Habiba et al., 2012), Chile (Roco et al., 2015) and Kenya (Muita et al., 2016). Most of these studies reported that farmers' perceptions of climate change and variability are in line with the actual analysis from meteorological data. Our study findings on farmers' perceptions' of climate change is also consistent with scientific observations (Chaudhary and Bawa, 2011; Shrestha et al., 1999). The ability of farmers to observe changes in local climatic conditions provides supplementary information in addition to the records taken in meteorological stations. Thus, while designing adaptation interventions in the agricultural sector, farmers' knowledge and skills should also be taken into consideration.

This study indicates that farming has been affected by climatic variability and change in a wide variety of ways that include an increase in drought periods and intensity, a shortage of irrigation water availability, an increase in flooding and landslides, pest infestation of crops, a rising number of crop diseases, the introduction of invasive species and crop weeds, soil degradation and an overall reduction in crop yields. A majority of farmers are responding to the impacts of climate change through adjustment in farming practices. An interesting finding of this study is the mismatch between the importance of adaptation practices and their actual level of adaptation at the farm

Table 5
Details of adaptation practices in cultivation of rice, maize, and wheat.

Adaptation practices	Rice (n = 422)			Maize (n = 382)			Wheat (n = 160)		
	Frequency (%)	Started since (years)	Exercised area (%)	Frequency (%)	Started since (years)	Exercised area (%)	Frequency (%)	Started since (years)	Exercised area (%)
Grow drought-tolerant varieties	23.46	3.64	50.21	14.66	5.02	55.32	10.63	5.85	37.05
Grow short duration varieties	22.51	9.67	52.23	19.63	6.16	58.14	20.00	6.84	74.21
Grow disease/pest resistant varieties	13.98	6.63	49.12	12.04	4.50	63.62	30.63	4.41	76.12
Grow flood tolerant varieties	15.17	4.08	50.88						
Grow cold tolerant varieties							8.75	6.00	47.50
Change planting location of varieties	21.09	5.31	50.15	13.87	4.72	55.91	4.38	5.43	66.43
Increase seeding rate	16.35	8.13	80.34	9.16	6.94	56.32	41.88	7.16	94.47
Cultivation of direct seeded rice	2.37	7.08	59.58						
Change/sowing/ planting/harvesting date	17.30	6.17	54.72	17.28	4.49	53.23	5.00	6.67	45.00
Seed priming	21.80	8.49	89.85	10.47	12.45	87.63	2.50	8.45	90.02
Improve/increase irrigation	15.64	7.69	57.63	19.63	6.01	88.73	7.50	4.50	54.17
Sowing seed at deeper depth				7.85	7.76	86.82			
Increasing number of earthing-up				10.21	5.23	47.25			
Reducing number of earthing-up				9.16	5.98	52.01			
Construction of waterways during heavy rainfall	24.64	6.96	41.26	6.54	5.43	35.48	5.00	6.87	50.63
Reduce tillage	8.29	4.05	19.61	11.26	4.39	49.37	8.13	6.54	64.23
Increasing number of weedings	18.48	11.41	53.54	12.57	6.21	65.32			
Soil conservation techniques	13.27	4.42	36.32	11.78	5.83	23.86	2.50	5.00	51.25
Improve/increase chemical fertilizer use	22.99	7.34	57.10	25.13	6.61	55.00	13.13	5.47	70.71
Improve/increase farm yard manure use	33.41	9.30	70.74	46.34	7.18	73.96	10.63	10.23	74.12
Use more pesticides	15.40	4.46	58.71	13.61	4.38	45.32	19.38	4.64	79.67

Table 6
Multiple regression results.

Variable	Overall (n = 720)		Rice (n = 422)		Maize (n = 382)		Wheat (n = 160)	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Age	−0.049**	−2.039	−0.038	−0.850	−0.041	−0.699	0.032	0.915
Education	0.384**	2.393	0.14***	3.065	0.176***	3.528	0.168***	4.495
Family size	−0.109***	−5.001	−0.094**	−2.118	−0.0742	1.035	−0.042	0.886
Land	0.068	0.915	0.078	1.319	0.081	3.613	0.075	0.828
Non-farm	0.049**	2.256	0.117***	2.788	0.135**	2.274	0.097***	2.867
Credit	0.215***	3.573	0.102**	2.347	0.066	1.107	0.087**	2.583
Extension	0.193**	2.255	0.037	0.823	0.144***	2.754	0.047	0.997
Market	−0.026	−1.206	−0.045	−2.044	0.038	0.768	−0.054	1.105
Institution	0.049	1.175	0.107	1.206	0.073	1.215	0.061	1.007
Drought/ flood	0.450***	6.065	0.307**	2.506	0.347**	2.419	0.278*	1.782
Plots	0.167***	2.812	0.294***	6.373	0.124***	3.154	0.112	1.356
Climate information	0.042**	1.979	0.119**	2.542	0.115**	2.257	0.128**	2.574
Climate belief	0.062***	2.813	0.137***	3.043	0.124**	2.476	0.112***	2.725
Adaptation belief	0.111***	4.905	0.085**	2.214	0.131*	1.775	0.098**	2.467
R-square	0.689		0.375		0.347		0.283	
F-value	117.708***		10.753***		10.643***		10.578***	

* $=p < 0.1$, ** $=p < 0.05$ and *** $=p < 0.01$.

level. In comparing adaptation practices and their level of adaptation it is shown that growing diverse crops and varieties, irrigation improvements, farm yard manure management and changing planting and harvesting date are important. A relatively larger percentage of farmers are adopting these practices. However, the adaptation practices such as growing drought tolerant species, use of less water, use of disease and insect resistant crops and varieties are shown to be important in all three agro-ecological regions. Yet, a relatively smaller percentage of farmers are adopting these practices in their farm lands. In addition, farmers have responded differently to climate change impacts for different crops. The differences in adoption of adaptation practices in rice, maize, and wheat may be attributed to the differential impacts of climate change on these crops. As most of rice cultivation is undertaken under rain-fed conditions in Nepal, low water demanding varieties can produce a better yield in drier climatic conditions. Thus, farmers can choose to grow drought tolerant rice varieties as an adaptive measure to combat climate change and the resultant long dry spells. Changes in temperature play an important role in disease infestation in wheat (Wosula et al., 2017). As the temperature becomes warmers, farmers can therefore choose to grow disease-resistant varieties.

The results further indicate that the level of adaptation rate is low and there exist several barriers to use of adaptation practices. More specifically, our findings suggest the need for easier access to information on climate change, adaptation practices, and technical knowledge on adaptation implementation. Use of adaptation practices are also affected by characteristics of farming households and their farms. They include age, education, family size, income sources, access to credit and extension services, the number of farm plots, climate change experience, information on climate change, belief in climate change and, belief in adaptation. The results emphasize the need for greater access to education, credit, extension services, and information on climate change to support farming households in making adaptation decisions. Moreover, policies aimed at planning adaptation programs need to emphasize the crucial role of socio-economic characteristics and should aim at implementing adaptation programs through research based on farmers' social, economic and attitudinal characteristics. These findings are particularly important from an applied perspective as they provide important information for extension officers, NGOs and local governments to plan and implement adaptation strategies at the local level.

To conclude, this study's primary objective was to develop an adaptation index that can be empirically used in measuring the adaptation practices adopted by farmers. We believe that that the model developed in measuring the adaptation index could serve the purpose of comparing levels of adaptation between farmers and their groups. In addition, such an integrated adaptation index can be utilized to investigate the factors influencing farmers' decisions on adoption of adaptation practices and in assessing the impact of adaptations on farm production and farmers' welfare. Furthermore, this approach of creating an index can be employed for developing a technology adoption index among smallholder farmers in less developed countries where a single farmer generally adopts various techniques on a smaller scale.

This study does have limitations. First, it is based on data collected from a sample of households in six districts of Nepal. Since data were collected from only two VDCs in the selected districts, the findings cannot necessarily be applied to other districts. Secondly, this study aggregates the level of adaptation into an index taking into account all different types of adaptation practices. It would be equally important to investigate the factors that influence farmers' uptake of specific adaptation practices at the farm level.

Acknowledgments

We thank the editor and the referees of this journal for their useful suggestions. The financial support provided by the Endeavour postgraduate scholarship of the Australian Government, and the QUT Business School, Queensland University of Technology, Australia is greatly appreciated. We are thankful to the farmers and stakeholders who shared their knowledge and information.

References

Abdulai, A., Huffman, W., 2014. The adoption and impact of soil and water conservation technology: an endogenous switching regression application. Land Econ. 90 (1), 26–43.
Alauddin, M., Sarker, M.A.R., 2014. Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. Ecol. Econ. 106, 204–213.
Anley, Y., Bogale, A., Haile-Gabriel, A., 2007. Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia. Land Degrad. Dev. 18 (3), 289–302.
Bandara, J.S., Cai, Y., 2014. "The impact of climate change on food crop productivity, food prices and food security in South Asia". Econ. Anal. Policy 44 (4), 451–465.
Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., Tscherning, K., 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Glob. Environ. Change 22 (1), 223–235.

Chaudhary, P., Bawa, K.S., 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. Biol. Lett rsbl20110269.
Chhetri, N., Chaudhary, P., Tiwari, P.R., Yadaw, R.B., 2012. Institutional and technological innovation: understanding agricultural adaptation to climate change in Nepal. Appl. Geogr. 33, 142–150.
Croppenstedt, A., Demeke, M., Meschi, M.M., 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Rev. Dev. Econ. 7 (1), 58–70.
Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob. Environ. Change 19 (2), 248–255.
Di Falco, S., Veronesi, M., Yesuf, M., 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am. J. Agric. Econ. 93 (3), 829–846.
Dissanayake, S., Mahadevan, M., Asafu-Adjaye, J., 2019. Is there a role for trade liberalization in mitigating the impacts of climate change on agriculture? Econ. Anal. Policy 62, 307–324.
Easterling, W., Aggarwal, P., Batima, P., Brander, K., Bruinsma, J., Erda, L., Baethgen, W., 2007. Food, fibre, and forest products. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press., Cambridge, pp. 273–313.
Esham, M., Garforth, C., 2013. Agricultural adaptation to climate change: insights from a farming community in Sri Lanka. Mitig. Adapt. Strateg. Glob. Change 18 (5), 535–549.
Fosu-Mensah, B.Y., Vlek, P.L., MacCarthy, D.S., 2012. Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. Environ. Dev. Sustain. 14 (4), 495–505.
Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob. Environ. Change 15 (3), 199–213.
Gunathilaka, R.P.D., Smart, J.C., Fleming, C.M., 2018. Adaptation to climate change in perennial cropping systems: options, barriers and policy implications. Environ. Sci. Policy 82, 108–116.
Habiba, U., Shaw, R., Takeuchi, Y., 2012. Farmer's perception and adaptation practices to cope with drought: perspectives from Northwestern Bangladesh. Int. J. Disaster Risk Reduct. 1, 72–84.
Hahn, M.B., Riederer, A.M., Foster, S.O., 2009. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change-a case study in Mozambique. Glob. Environ. Change 19 (1), 74–88.
Halder, P., Sharma, R., Alam, A., 2012. Local perceptions of and responses to climate change: experiences from the natural resource-dependent communities in India. Reg. Environ. Change 12 (4), 665–673.
Hassan, R., Nhemachena, C., 2008. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. Afr. J. Agric. Resour. Econ. 2 (1), 83–104.
Huang, J., Wang, Y., Wang, J., 2015. Farmers' adaptation to extreme weather events through farm management and its impacts on the mean and risk of rice yield in China. Am. J. Agric. Econ. 97 (2), 602–617.
Jawid, A., Khadjavi, M., 2019. Adaptation to climate change in Afghanistan: evidence on the impact of external interventions. Econ. Anal. Policy 64, 64–82.
Khanal, U., 2014. Perception and adaptation of the producers to the impacts of climate change in apple production: an assessment of Mustang district of Nepal. J. Agric. Environ. 15, 11–17.
Khanal, U., Wilson, C., Hoang, V.N., Lee, B., 2018. Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal". Ecol. Econ. 144, 139–147.
Lata, S., Nunn, P., 2012. Misperceptions of climate-change risk as barriers to climate-change adaptation: a case study from the Rewa Delta, Fiji. Clim. Change 110 (1-2), 169–186.
Li, S., Juhász-Horváth, L., Harrison, P.A., Pintér, L., Rounsevell, M.D., 2017. Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. J. Environ. Manage. 185, 21–30.
Malla, G., 2009. Climate change and its impact on Nepalese agriculture. J. Agric. Environ. 9, 62–71.
Manandhar, S., Vogt, D.S., Perret, S.R., Kazama, F., 2011. Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices". Reg. Environ. Change 11 (2), 335–348.
Measham, T.G., Preston, B.L., Smith, T.F., Brooke, C., Gorddard, R., Withycombe, G., Morrison, C., 2011. Adapting to climate change through local municipal planning: barriers and challenges. Mitig. Adapt. Atrategies Global Change 16 (8), 889–909.
MoAD, 2012. Statistical information on Nepalese agriculture 2011/12. Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division. Agri statistics Section, Singha Durbar, Kathmandu, Nepal.
MoE, 2010. National Adaptation Programme of Action to Climate Change. Ministry of Environment, Kathmandu, Nepal.
MoF, 2014. Economic Survey: Fiscal Year 2013/14. Ministry of Finance, Kathmandu, Nepal.
Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture". Proc. Natl. Acad. Sci. 104 (50), 19680–19685.
Muita, R.R., van Ogtrop, F., Ampt, P., Vervoort, R.W., 2016. Managing the water cycle in Kenyan small-scale maize farming systems: Part 1. Farmer perceptions of drought and climate variability". Wiley Interdiscip. Rev. Water 3 (1), 105–125.
Nielsen, J.Ø., Reenberg, A., 2010. Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. Glob. Environ. Change 20 (1), 142–152.
Niles, M.T., Brown, M., Dynes, R., 2016. Farmer's intended and actual adoption of climate change mitigation and adaptation strategies. Clim. Change 135 (2), 277–295.
Nyangena, W., 2008. "Social determinants of soil and water conservation in rural Kenya. Environ. Dev. Sustain. 10 (6), 745–767.
Osbahr, H., Dorward, P., Stern, R., Cooper, S., 2011. Supporting agricultural innovation in Uganda to respond to climate risk: linking climate change and variability with farmer perceptions". Exp. Agric. 47 (02), 293–316.
Piya, L., Maharjan, K.L., Joshi, N.P., 2012. Perceptions and realities of climate change among the Chepang communities in rural mid-hills of Nepal. Journal of Contemporary India Studies: Space and Society 2, 35–50.
Piya, L., Maharjan, K.L., Joshi, N.P., 2013. Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal. Reg. Environ. Change 13 (2), 437–447.
Roco, L., Engler, A., Bravo-Ureta, B.E., Jara-Rojas, R., 2015. Farmers' perception of climate change in mediterranean Chile". Reg. Environ. Change 15 (5), 867–879.
Shrestha, A.B., Wake, C.P., Mayewski, P.A., Dibb, J.E., 1999. Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. J. Clim. 12 (9), 2775–2786.
Sofoluwe, N., Tijani, A., Baruwa, O., 2011. Farmers perception and adaptation to climate change in Osun State, Nigeria". Afr. J. Agric. Res. 6 (20), 4789–4794.
Wang, J., Huang, X., Zhong, T., Chen, Z., 2013. Climate change impacts and adaptation for saline agriculture in north Jiangsu Province. China. Environmental Science & Policy 25, 83–93.
Wosula, E., Tatineni, S., Wegulo, S., Hein, G., 2017. Effect of temperature on wheat streak mosaic disease development in winter wheat". Plant Dis. 101 (2), 324–330.